Converting Fast Pass/Fast Fail Emissions Results to Full IM240 Equivalents

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June 17, 1999

At least 4 methods have been used to convert fast-pass/fail emissions to full IM240 emissions: 1) a method developed by LBNL for use in analyzing the Arizona I/M program (LBNL; Wenzel, 1997); 2) a method developed by Peter McClintock of Applied Analysis, with input from Rob Klausmeier and the Colorado Department of Public Health and Environment, for use in the Colorado I/M program (PM; McClintock, 1998)[1]; 3) a method developed by Resources for the Future, also for use in analyzing the Arizona program (RFF; Ando et al, 1998), and 4) a method developed by EPA using data from Wisconsin and applied to Ohio fast pass data EPA; (EPA; Enns, 1999, and personal communication). The LBNL method is based on the average ratio of emissions at each second to full test emissions from a sample of 4,000 vehicles receiving the full IM240 in Arizona in 1992.[2] The LBNL method involves dividing emissions at a given second by a correction factor, based only on the second of testing (and not on other variables, such as vehicle age or type). The McClintock and RFF methods are similar; they rely on regression models generated for many subsets of the data. The McClintock method accounts for vehicle age and type, while the RFF method accounts for vehicle age and the product of the vehicle age and emissions level at a given second. The McClintock coefficients were calculated for 10 second intervals in the IM240 trace; coefficients for interlying seconds are determined by interpolation. The RFF method estimates <u>negative</u> emissions values for some vehicles with very low emissions at second 31. The EPA method is based on a single regression equation for the entire vehicle fleet. The equation includes coefficients for the log of fast pass emissions, the last second of the test, and dummy variables for whether the vehicle is fuel injected or carbureted, a car or a truck, and for 14 model years.[3]

This memo examines the accuracy of such methods in predicting full IM240 emissions. First, we compare the accuracy of each of the three methods on a sample of vehicles whose full test emissions are known. Then we apply the PM and LBNL method to Wisconsin data, to see what effect different methods have on fleet emissions estimates. Finally, we evaluate the accuracy of the LBNL method by comparing the distribution of emissions of fast pass/fast fail vehicles with that of the random sample of vehicles receiving the full IM240.

Comparison of Three Methods

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[1]. Developed in late 1995 and early 1996 with inputs from Rob Klausmeier and CDPHE.

[2]. The testing was conducted by Automotive Testing Laboratory, under contract with EPA. The vehicles tested may not be a random sample of vehicles.

[3]. We could not perfectly match EPA's results when we applied EPA's methodology to the Ohio data. We calculated the Ohio fleet emissions to be 18% higher for HC, 7% higher for CO, and 8% higher for NOx than as calculated by EPA, apparently using the same conversion method.

We used the random sample (Jan-June 1996) of vehicles given a full IM240 in Arizona to test the accuracy of three different methods in accurately predicting full IM240 emissions from vehicles passing after only 30 seconds of testing. We first identified which vehicles in the random sample would have passed EPA-recommended fast-pass cutpoints at second 30; there are 2,197 such passenger cars in the random sample. Then, we calculated what each vehicle's estimated full IM240 emissions would be under each conversion method. We analyzed cars from model years 1983 to 1990, and model years 1991 and newer, separately, since different fast pass cutpoints are applied to these two model year groups. (A more thorough analysis would predict at which second each vehicle would have fast-passed or fast-failed the IM240, and then make the adjustments to all of the vehicles in the sample. We focus here on the vehicles that fast-pass at second 30 to simplify the analysis, and because the majority of vehicles that fast-pass pass at this second.)

Table 1 shows the average emissions for these groups of vehicles over the full IM240 test, as measured under the program and as estimated by the three conversion methodologies. (The EPA method is calculated for MY81-94 cars only; the analysis was not applied to the 297 MY95 and newer cars in the Arizona sample. The EPA method was not applied to 77 cars in the MY83-90 group for which type of fuel delivery system was not readily available for the Arizona data. Restricting the analysis to only those cars that can be analyzed using the EPA method does not change the results.) The method that best predicts the emissions for each vehicle group and pollutant is noted in bold type in the table. In general, the LBNL method tends to underestimate the full test emissions of fast-passed cars; this underestimation is greatest for CO emissions, and for emissions from older vehicles. On the other hand, the PM method tends to overestimate emissions. The RFF method predicts emissions from older cars more accurately than from newer cars, while the LBNL method predicts emissions from newer cars more accurately. The RFF method estimates that full test NOx emissions of MY91+ cars are only 30% of their measured emissions; this large underestimation is because the RFF method predicts that over 35% of these vehicles would have had negative NOx emissions over the full IM240 (rounding the emissions of these vehicles to zero raises the fleet NOx emissions to 0.14 gpm, and raises the ratio of estimated to measured NOx to 0.31). When applied to Arizona data, the EPA method drastically underestimates emissions of all three pollutants, in both model year groups.

Table 1. Measured and Predicted full IM240 Emissions under Four Prediction Methods

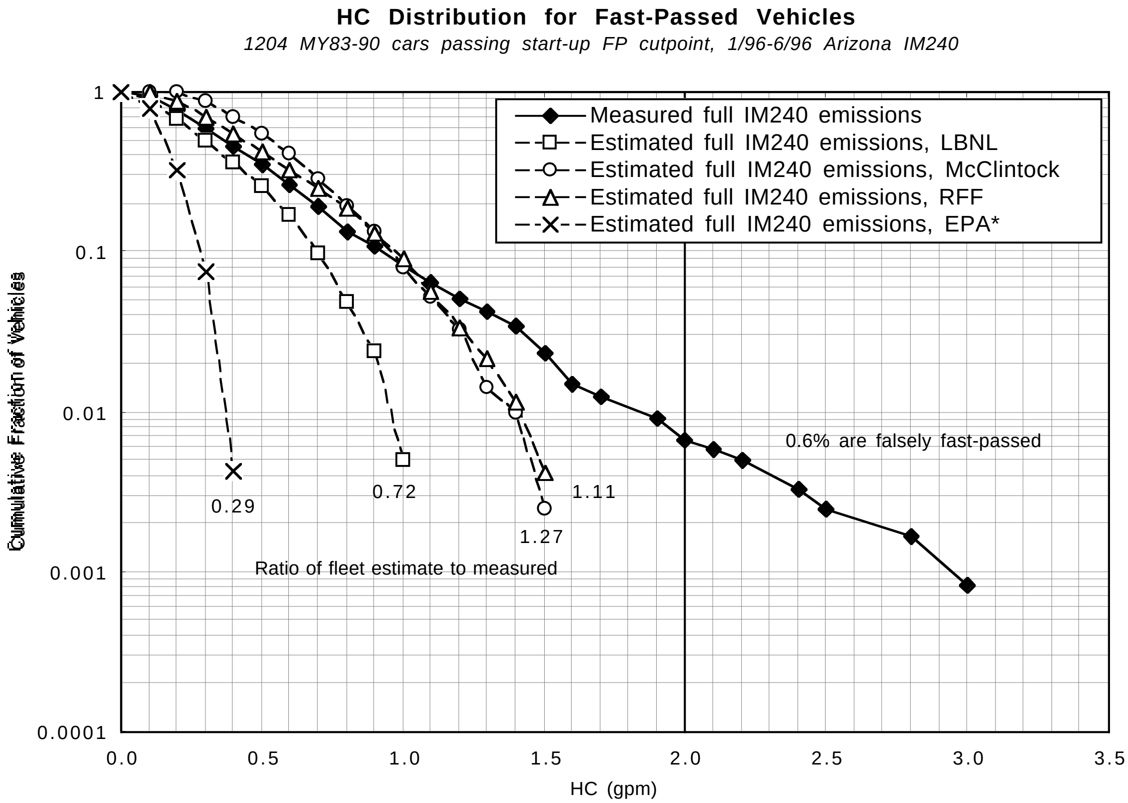
	Average emissions, gpm			Ratio of estimated to measured		
	HC	CO	NOx	HC	CO	NOx
MY83-90 (n=1,204)						
Measured	0.42	6.85	1.21	1.00	1.00	1.00
LBL	0.30	3.65	0.87	0.72	0.53	0.72
PM	0.53	9.55	1.14	1.27	1.40	**0.95**
RFF	0.46	7.05	0.91	**1.11**	**1.03**	0.76
EPA*	0.12	2.19	0.33	0.29	0.32	0.27
MY91+ (n=993)						
Measured	0.10	1.93	0.45	1.00	1.00	1.00
LBL	0.10	1.35	0.43	**1.01**	0.70	0.95
PM	0.15	3.35	0.46	1.45	1.74	**1.01**
RFF	0.08	1.56	0.11	0.79	**0.81**	0.24
EPA**	0.05	0.76	0.23	0.49	0.40	0.51

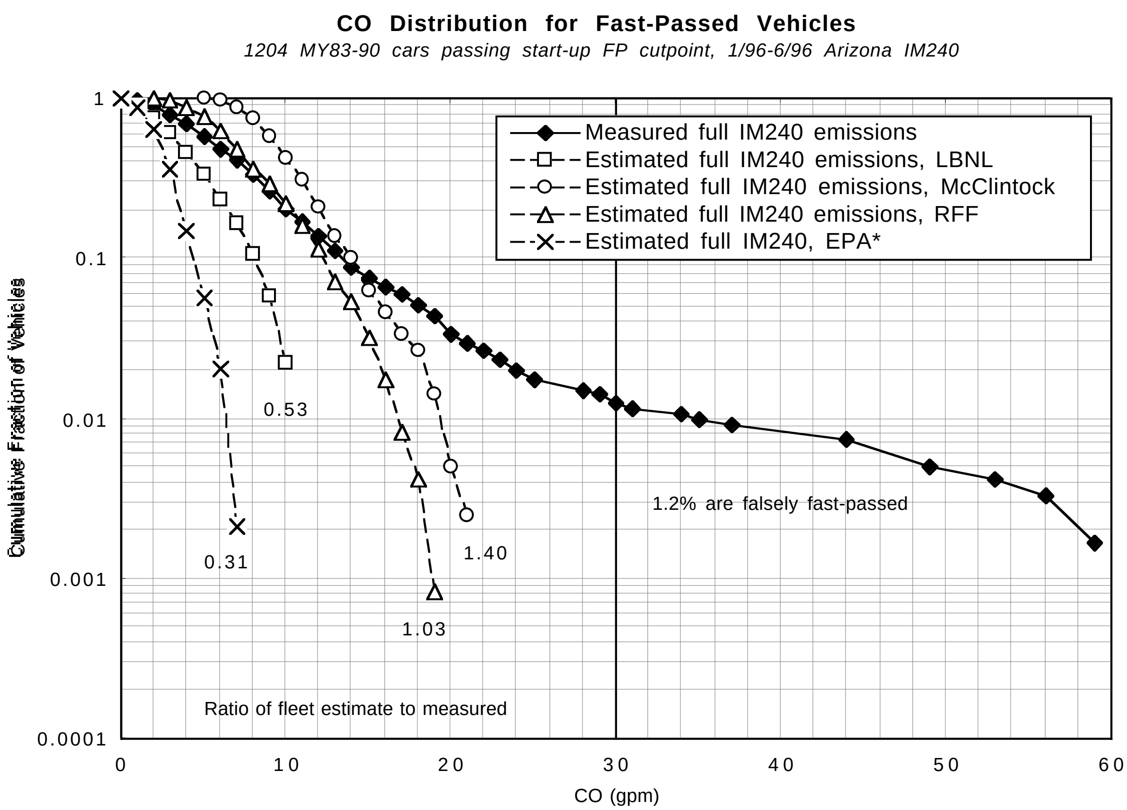
*The EPA method relies on type of fuel delivery system (carbureted or fuel injected); the analysis was not applied to 77 cars for which fuel delivery system was not readily available.

**The EPA method is calculated for MY81-94 cars only; the analysis was not applied to the 297 MY95 and newer cars in the Arizona sample.

The following six figures show the distribution of emissions, as measured and as estimated based on the three prediction methods. The figures also report the ratio of the estimated to the measured emissions for all vehicles, from Table 1 above. A few of the vehicles that would have been fast-passed (i.e. that had emissions at second 30 lower than the fast pass cutpoints) had emissions higher than the cutpoints applied to the full IM240 test. The figures indicate the portion of all vehicles that would have been falsely fast-passed if the fast-pass cutpoints were applied. For instance, none of the MY91 and newer cars would have been fast-passed for NOx, but 2 percent (24 cars) of the MY83-90 cars would have been falsely fast-passed for NOx.

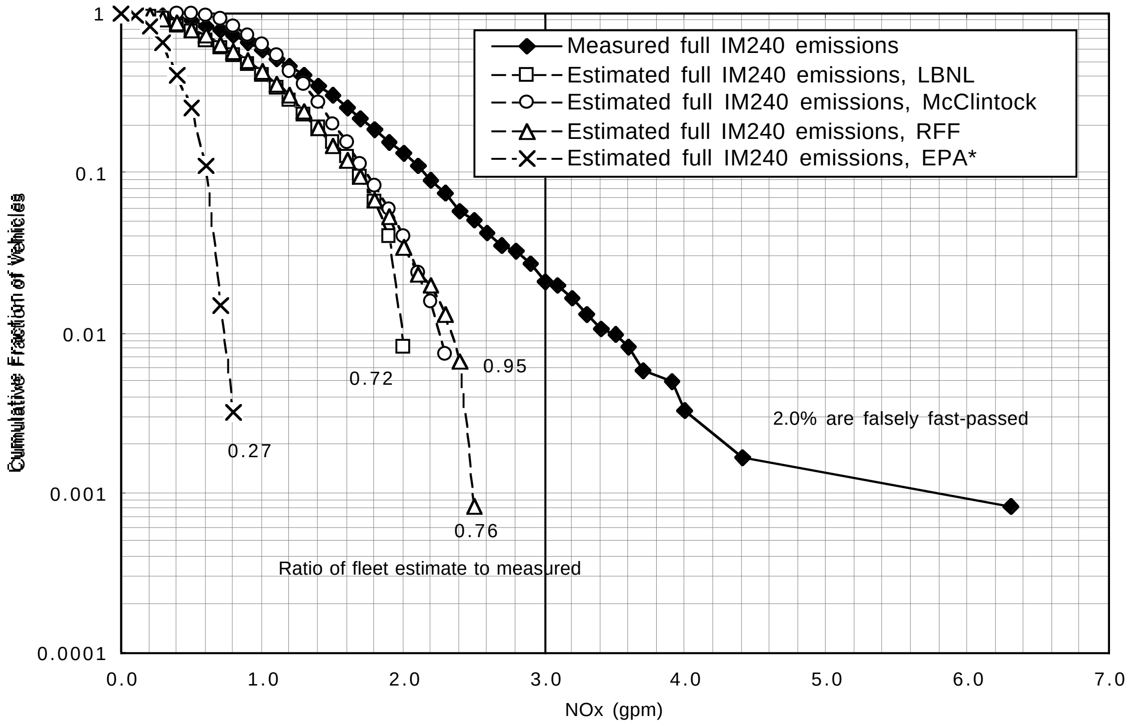
It should be noted that the RFF method was developed using some of the data used in this evaluation, and therefore should be expected to most accurately predict full test emissions. (The PM method was developed using Colorado IM240 data, the LBNL method was developed using earlier IM240 tests conducted in Tucson by Automotive Testing Laboratories, and the EPA method was developed using Wisconsin IM240 data.)


HC Distribution for Fast-Passed Vehicles
1204 MY83-90 cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240
Measured full IM240 emissions
Estimated full IM240 emissions, LBNL
Estimated full IM240 emissions, McClintock
Estimated full IM240 emissions, RFF
Estimated full IM240 emissions, EPA*
0.6% are falsely fast-passed
0.29
0.72
1.11
1.27
Ratio of fleet estimate to measured
Cumulative Fraction of Vehicles
HC (gpm)
1
0.1
0.01
0.001
0.0001
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


CO Distribution for Fast-Passed Vehicles
1204 MY83-90 cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240
Measured full IM240 emissions
Estimated full IM240 emissions, LBNL
Estimated full IM240 emissions, McClintock
Estimated full IM240 emissions, RFF
Estimated full IM240, EPA*
1.2% are falsely fast-passed
0.53
0.31
1.40
1.03
Ratio of fleet estimate to measured
Cumulative Fraction of Vehicles
CO (gpm)
1
0.1
0.01
0.001
0.0001
0
10
20
30
40
50
60

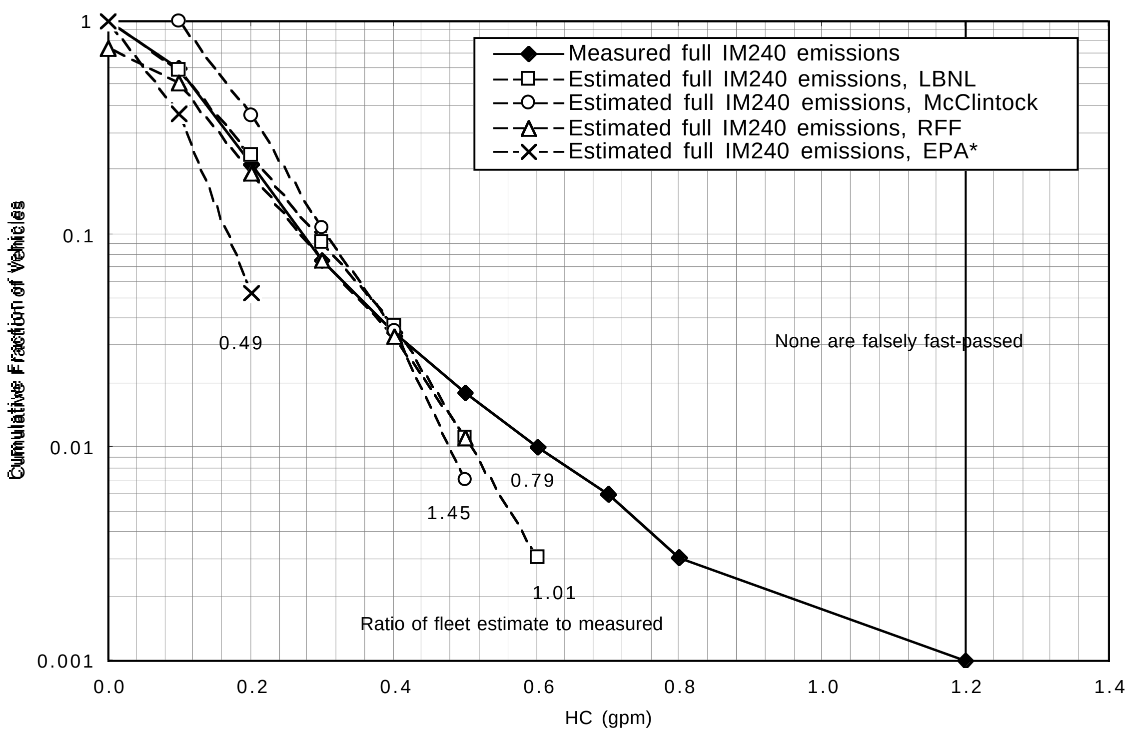
NOx Distribution for Fast-Passed Vehicles

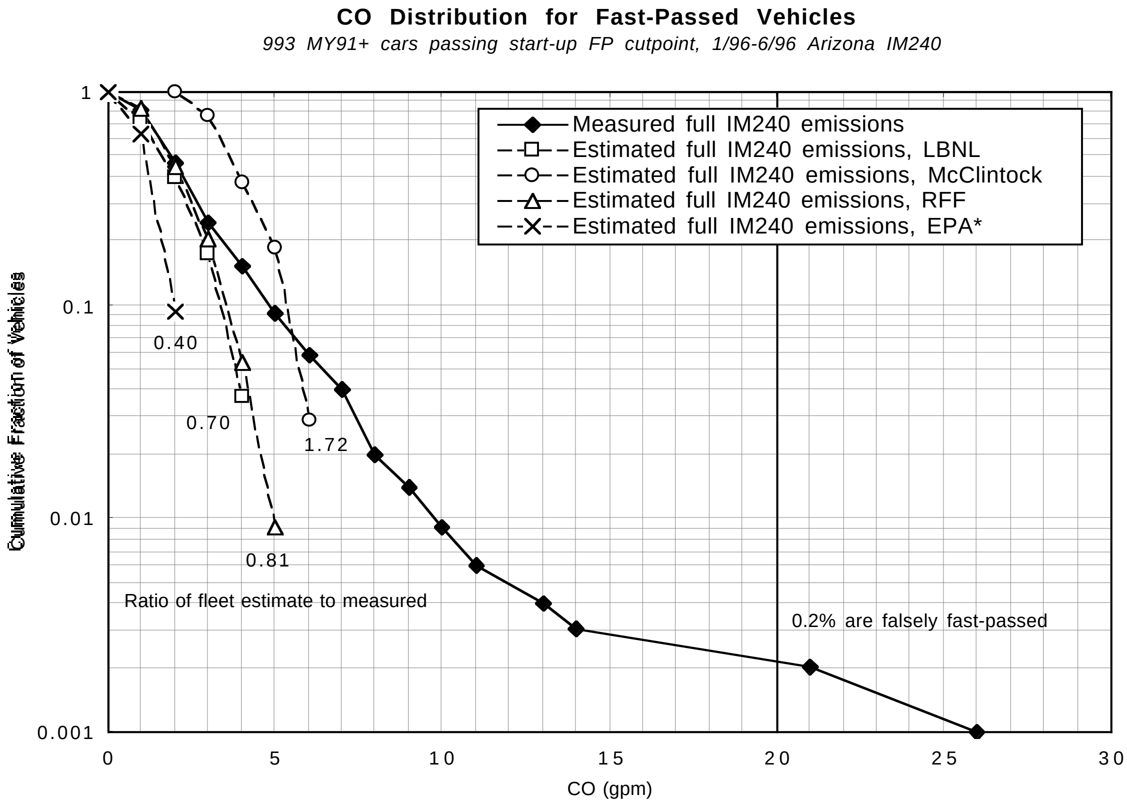
1204 MY83-90 cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240



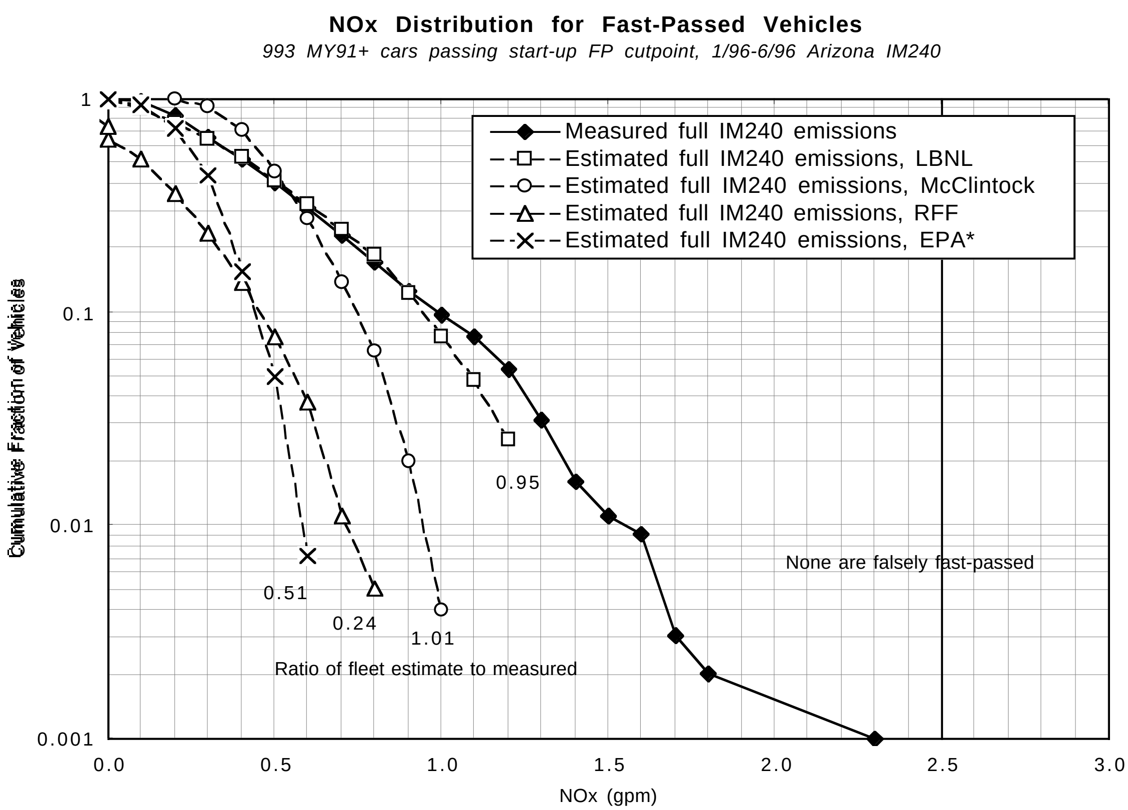
HC Distribution for Fast-Passed Vehicles

993 MY91+ cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240





CO Distribution for Fast-Passed Vehicles
993 MY91+ cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240
Measured full IM240 emissions
Estimated full IM240 emissions, LBNL
Estimated full IM240 emissions, McClintock
Estimated full IM240 emissions, RFF
Estimated full IM240 emissions, EPA*
Cumulative Fraction of Vehicles
1
0.1
0.01
0.001
0.40
0.70
1.72
0.81
Ratio of fleet estimate to measured
0.2% are falsely fast-passed
0
5
10
15
20
25
30
CO (gpm)



NOx Distribution for Fast-Passed Vehicles
993 MY91+ cars passing start-up FP cutpoint, 1/96-6/96 Arizona IM240
Measured full IM240 emissions
Estimated full IM240 emissions, LBNL
Estimated full IM240 emissions, McClintock
Estimated full IM240 emissions, RFF
Estimated full IM240 emissions, EPA*
Cumulative Fraction of Vehicles
1
0.1
0.01
0.001
0.95
None are falsely fast-passed
0.51
0.24
1.01
Ratio of fleet estimate to measured
0.0
0.5
1.0
1.5
2.0
2.5
3.0
NOx (gpm)

Two Methods Applied to Wisconsin Data

In order to determine the effect of using a different adjustment methodology on fleet average emissions, we applied the LBNL, PM, and EPA methods to an independent set of data from the Wisconsin IM240 program.[4] We also used the PM method based on a random sample of full tests conducted in Wisconsin, using data supplied by Peter McClintock. Table 2 shows the average emissions for the MY82 to MY94 passenger car fleet predicted by each method, as well as the ratio of the prediction under each method to the prediction under the PM method derived from Wisconsin data. The source of the data used for each method is listed in parentheses in Table 2. We only applied the data to vehicles for which we could identify their type of fuel delivery system, as the EPA method relies on this information. By restricting the analysis to these vehicles, we ensure that each method is applied to the same vehicles.

The LBNL method consistently predicts lower fleet emissions than the PM (Wisconsin) method, particularly for cars passed after only 30 seconds of testing. On the other hand, the EPA method predicts slightly higher fleet emissions than the PM (Wisconsin) method, especially for HC and NOx. The PM method based on Colorado data predicts the same fleet HC emissions as the PM (Wisconsin) method, but predicts higher CO emissions and lower NOx emissions. This type of analysis only tells us the relative effect of each prediction method on fleet emissions; we cannot say which method is more accurately predicting full test emissions.

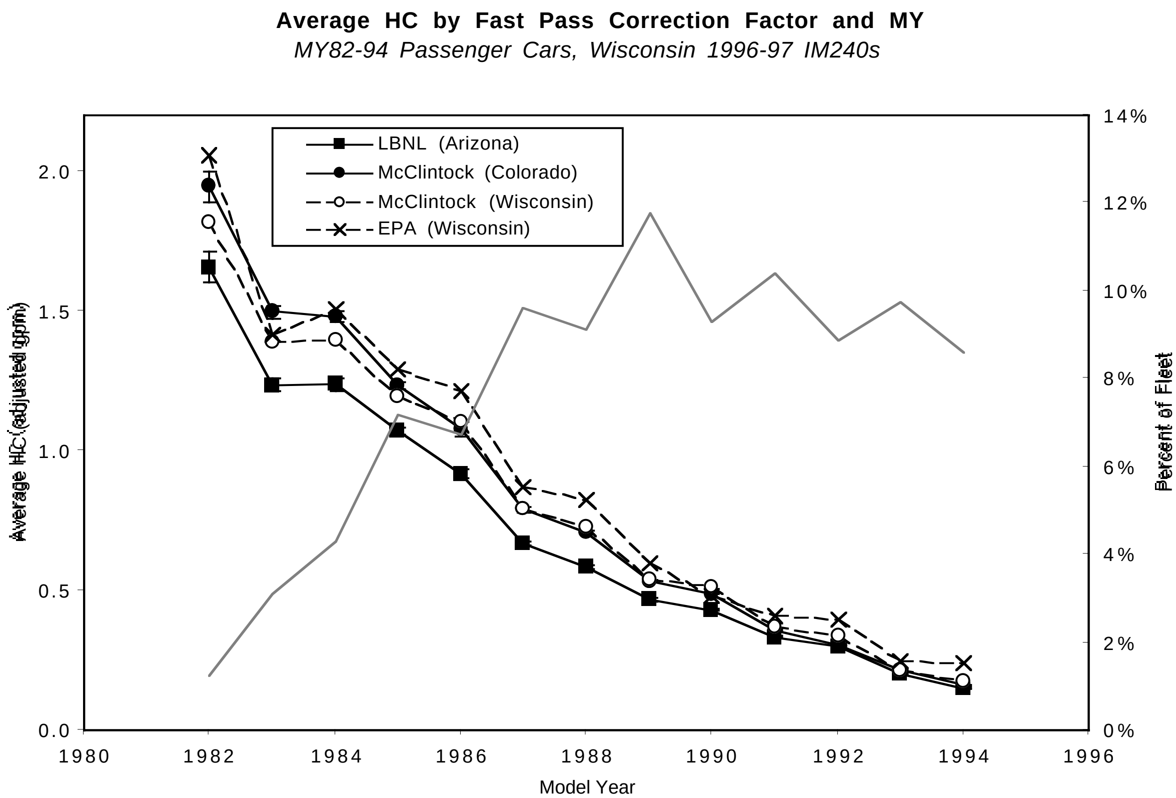
Table 2. Comparison of Different Methods on Wisconsin Data

	Average Predicted Emissions, gpm			**Ratio of Prediction to PM (Wisconsin) Prediction**		
	HC	CO	NOx	HC	CO	NOx
All tests						
LBNL (Arizona)	0.56	6.64	1.08	0.87	0.79	0.82
PM (Colorado)	0.64	9.94	1.15	**1.00**	1.18	0.87
PM (Wisconsin)	0.64	8.45	1.32	1.00	1.00	1.00
EPA (Wisconsin)	0.70	9.13	1.46	1.10	**1.08**	**1.11**
Cars passed after only 30 seconds of testing						
LBNL (Arizona)	0.23	2.26	0.71	0.62	0.45	0.68
PM (Colorado)	0.37	6.84	0.86	**1.00**	1.36	0.82
PM (Wisconsin)	0.37	5.02	1.04	1.00	1.00	1.00
EPA (Wisconsin)	0.43	5.22	1.18	1.15	**1.04**	**1.13**

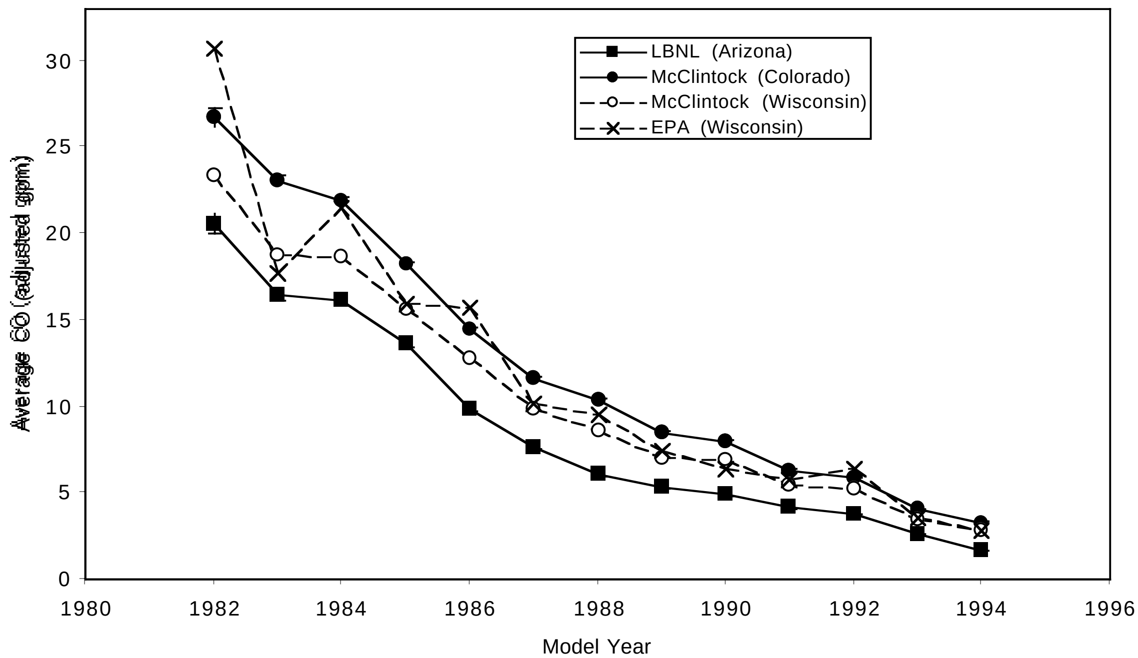
The next three figures compare the average adjusted emissions for all MY82 to MY94 passenger cars by model year, under each prediction method. The HC figure shows the percent distribution of cars by model year, as a gray line. Both of the methods based on Wisconsin data (the PM and EPA methods) result in higher emissions from even-year vehicles; this is particularly evident for NOx under the EPA method. These peaks are likely due to the sample of vehicles given the full test in Wisconsin, which were used to

[4]. Like Colorado, Wisconsin's IM240 program does not allow vehicles to fast fail; all vehicles with high emissions are given a full IM240.

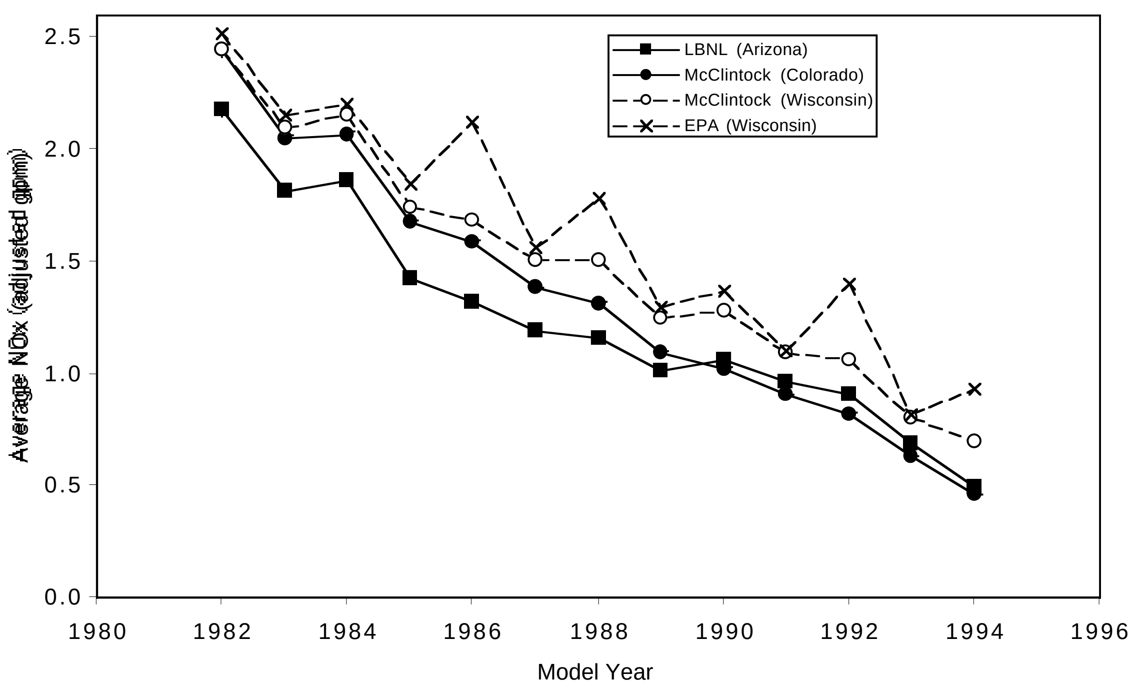
develop the adjustment methods. Most of this testing was conducted in 1996; therefore, most of these vehicles were from odd model years. McClintock's method results in smaller peaks because he grouped several model years together before calculating his adjustment factors.



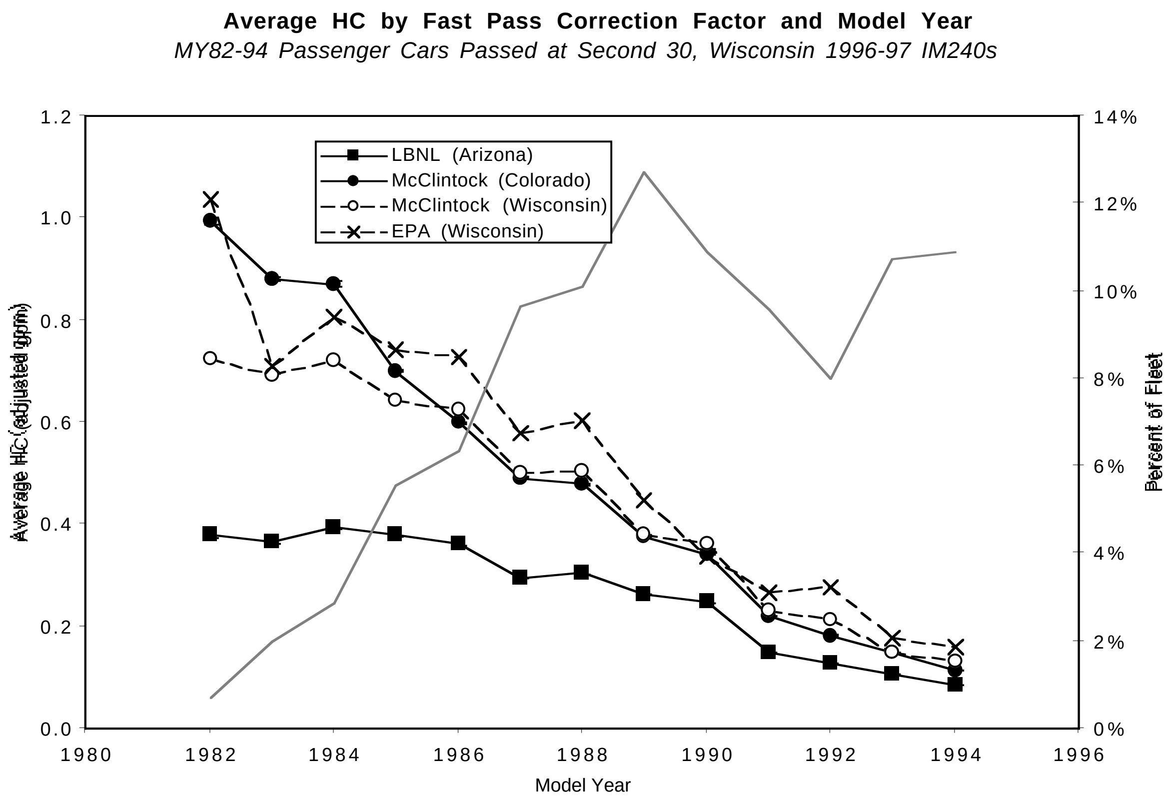
Average CO by Fast Pass Correction Factor and MY
MY82-94 Passenger Cars, Wisconsin 1996-97 IM240s



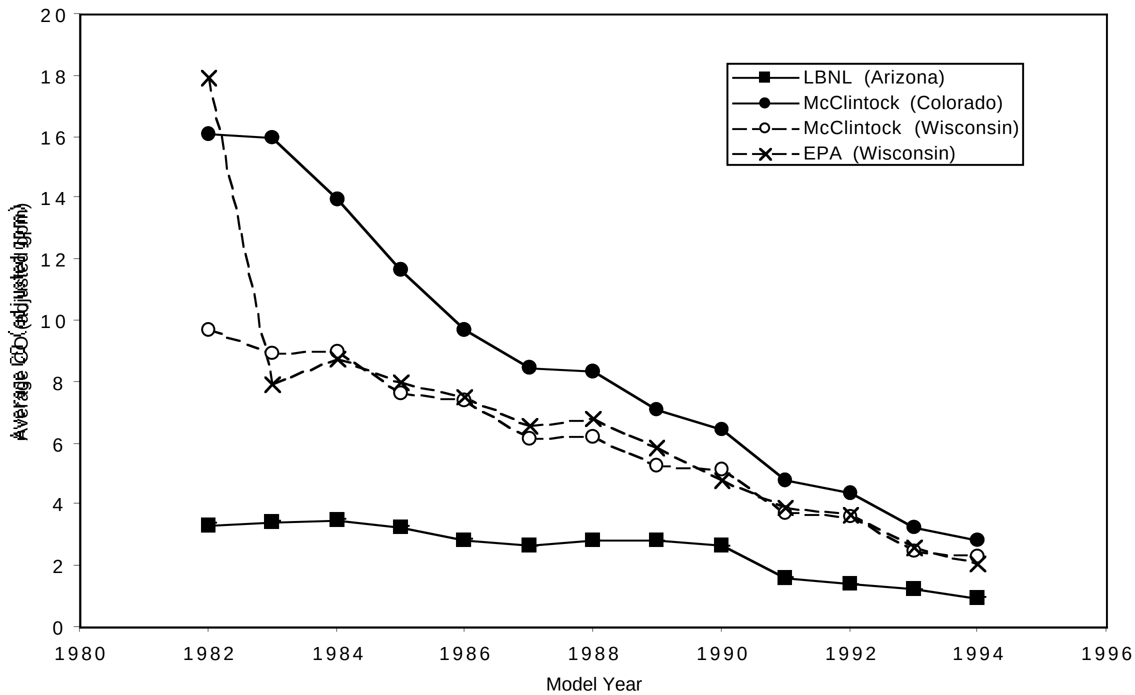
Average NOx by Fast Pass Correction Factor and MY
MY82-94 Passenger Cars, Wisconsin 1996-97 IM240s



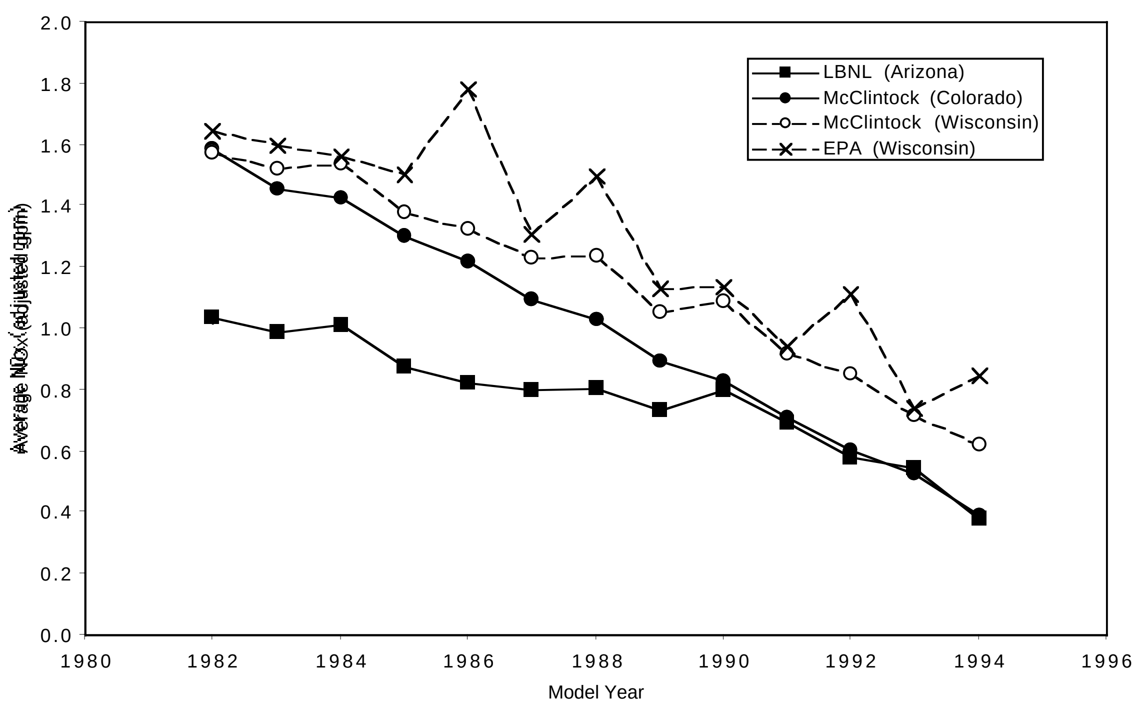
The next three figures compare the average emissions by model year for vehicles that are fast-passed after only 30 seconds of testing. The accuracy of an adjustment method after only 30 seconds of testing greatly affects the overall accuracy of the method, since most vehicles are passed at this time. In this sample nearly 70% of all cars were passed after only 30 seconds. Here we see much larger discrepancies between the LBNL method and the PM (Wisconsin) method, especially for older cars. Again, the HC figure shows the percent distribution of cars by model year, as a gray line.



Average CO by Fast Pass Correction Factor and Model Year
MY82-94 Passenger Cars Passed at Second 30, Wisconsin 1996-97 IM240s



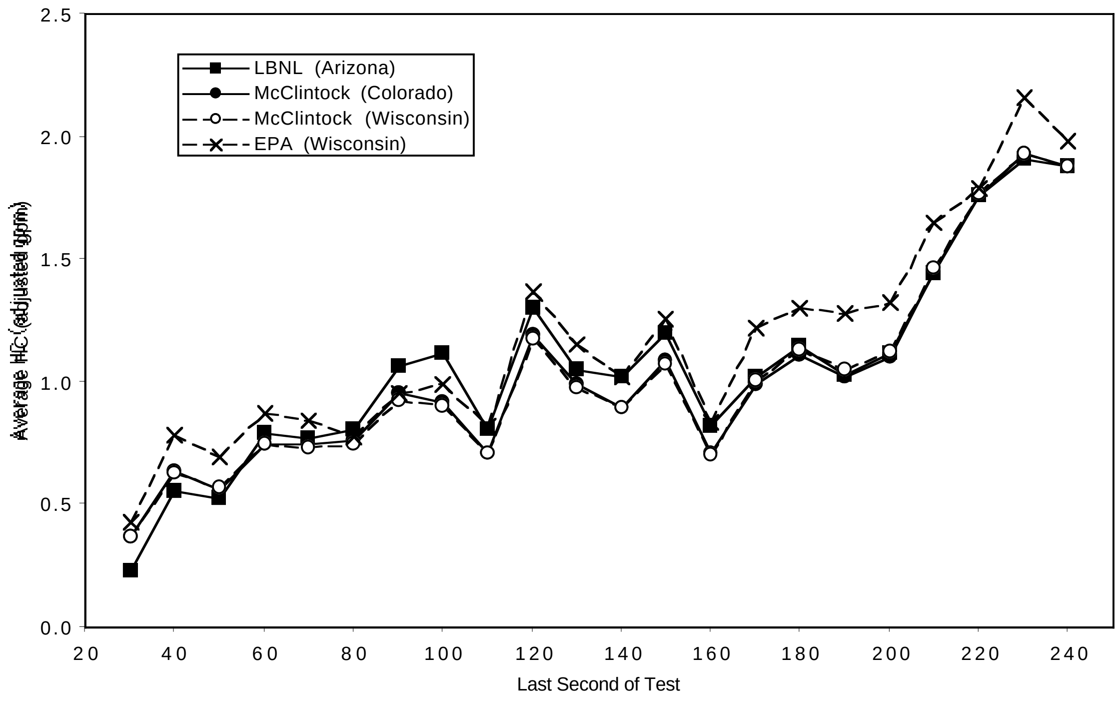
Average NOx by Fast Pass Correction Factor and Model Year
MY82-94 Passenger Cars Passed at Second 30, Wisconsin 1996-97 IM240s



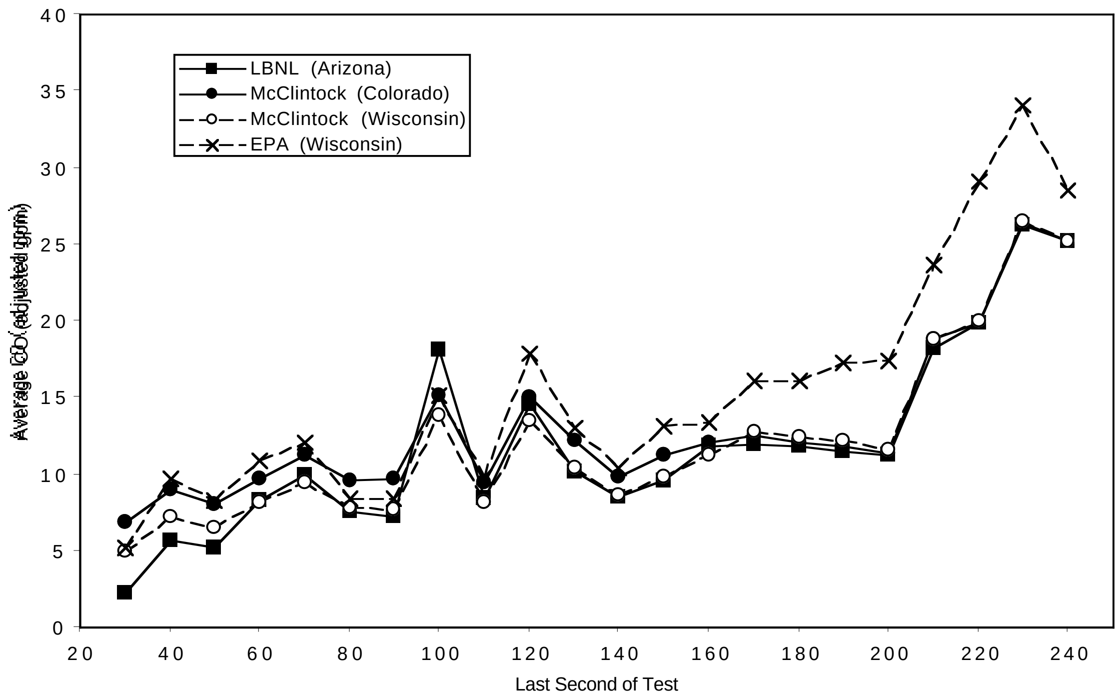
The next three figures show average emissions under each prediction method by the last second of the test. Average emissions at each 10-second point only are shown to reduce the complexity of the figure. Each method predicts relatively similar emissions to vehicles that are driven over different portions of the IM240 cycle; the shape of the curves by second of the test are quite similar using each prediction method. Nearly 70% of the cars are passed after only 30 seconds of testing; another 11% are given the full test. The test durations of the remaining 19% of the fleet are fairly evenly distributed over the other 209 seconds of the test.

Note that all but the EPA method converge the further into the test cars are driven; the emissions at second 240 for all but the EPA method are identical. (Since the EPA method should not be applied to cars given the full IM240 test, in the preceding tables and figures the measured values for full IM240s were substituted for the values "predicted" by the EPA method.) The EPA method results in much higher emissions for vehicles driven further into the test than the PM (Wisconsin) method, particularly for CO and NOx. However, as mentioned above, relatively few cars are fast-passed this far into the test.

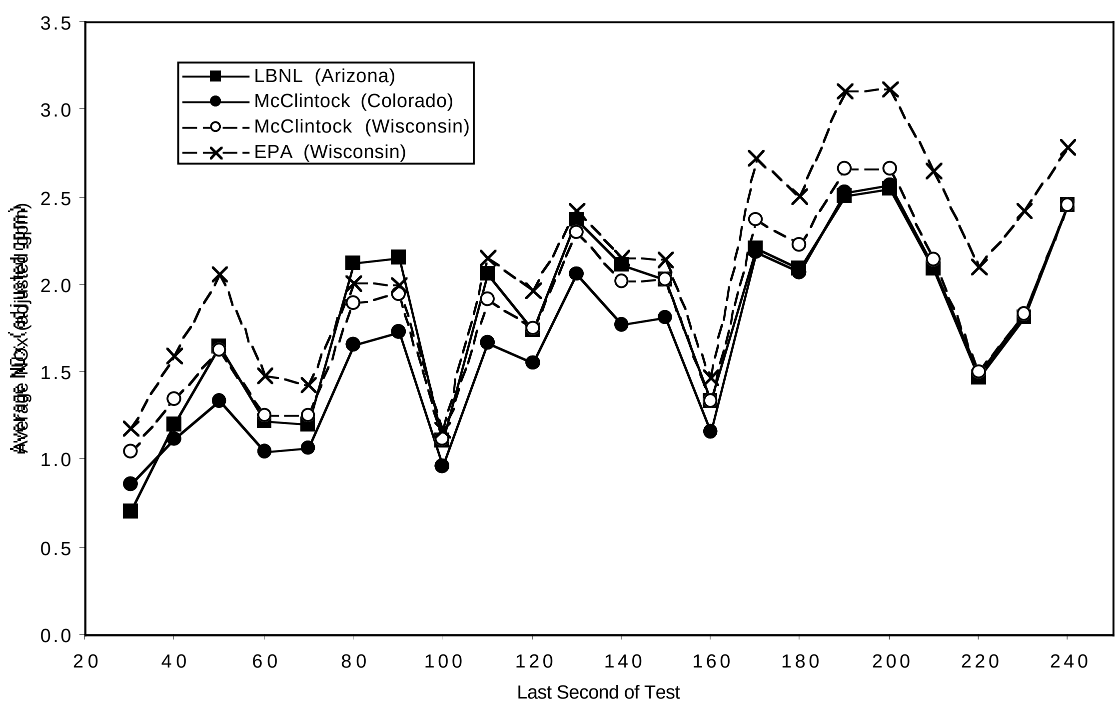
Average HC by Fast Pass Correction Factor and Last Second
MY82-94 Passenger Cars, Wisconsin 1996-97 IM240s



Average CO by Fast Pass Correction Factor and Last Second
MY82-94 Passenger Cars, Wisconsin 1996-97 IM240s



Average NOx by Fast Pass Correction Factor and Last Second
MY82-94 Passenger Cars, Wisconsin 1996-97 IM240s



Evaluation of LBNL Method

Finally, we compare the distribution of emissions from the random sample of vehicles given the full IM240 test in Arizona in 1996, with the adjusted emissions of the vehicles that were not given the full IM240 (i.e. those that were either fast-passed or fast-failed). The first figure compares the model year distribution of the cars in each sample, and indicates that the random sample appears to be quite representative of the entire population of vehicles tested under the Arizona I/M program.

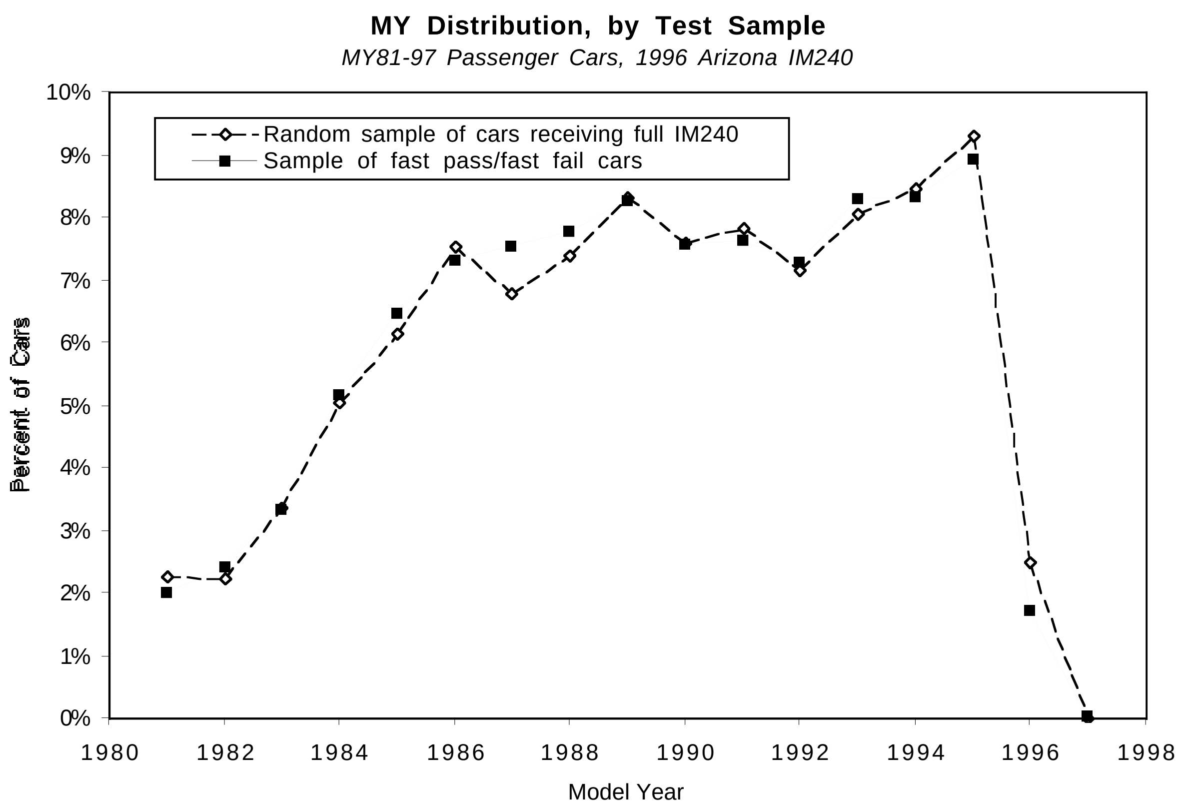


Table 3 compares the measured full test emissions, from the sample of vehicles given the full IM240, with the predicted full test emissions, from the vehicles fast-passing or fast-failing the Arizona IM240. The table indicates that the predicted emissions from the fast-pass/fast-fail vehicles are very similar to those from the random sample of vehicles.

Table 3. Comparison of Measured and Predicted Full Test Emissions, Arizona Random Sample and Fast-Pass/Fast-Fail Tests

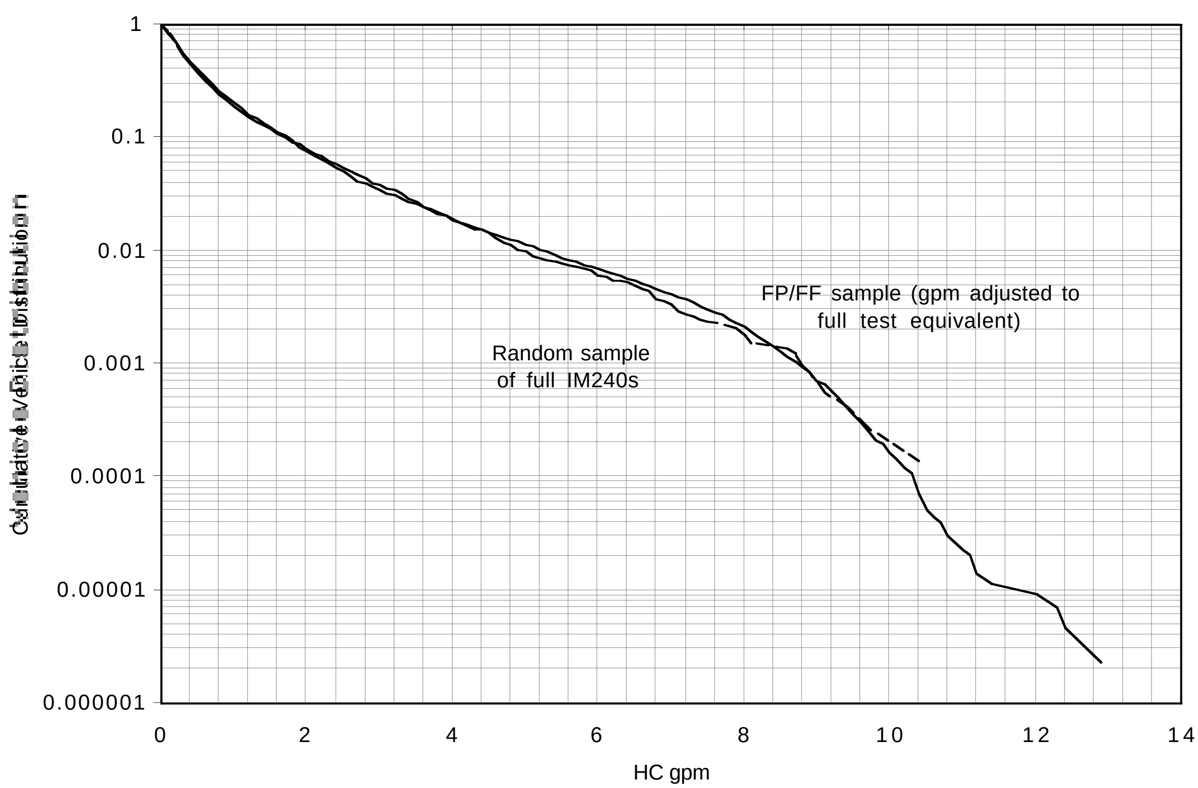
	Average emissions (gpm)			**Ratio of FP/FF to full test**		
	HC	**CO**	**NOx**	**HC**	**CO**	**NOx**
Random Sample (n=7,209)	0.64	10.3	1.23	1.00	1.00	1.00
Fast Pass/Fast Fail (n=436,160)	0.66	9.5	1.22	1.02	0.93	0.99

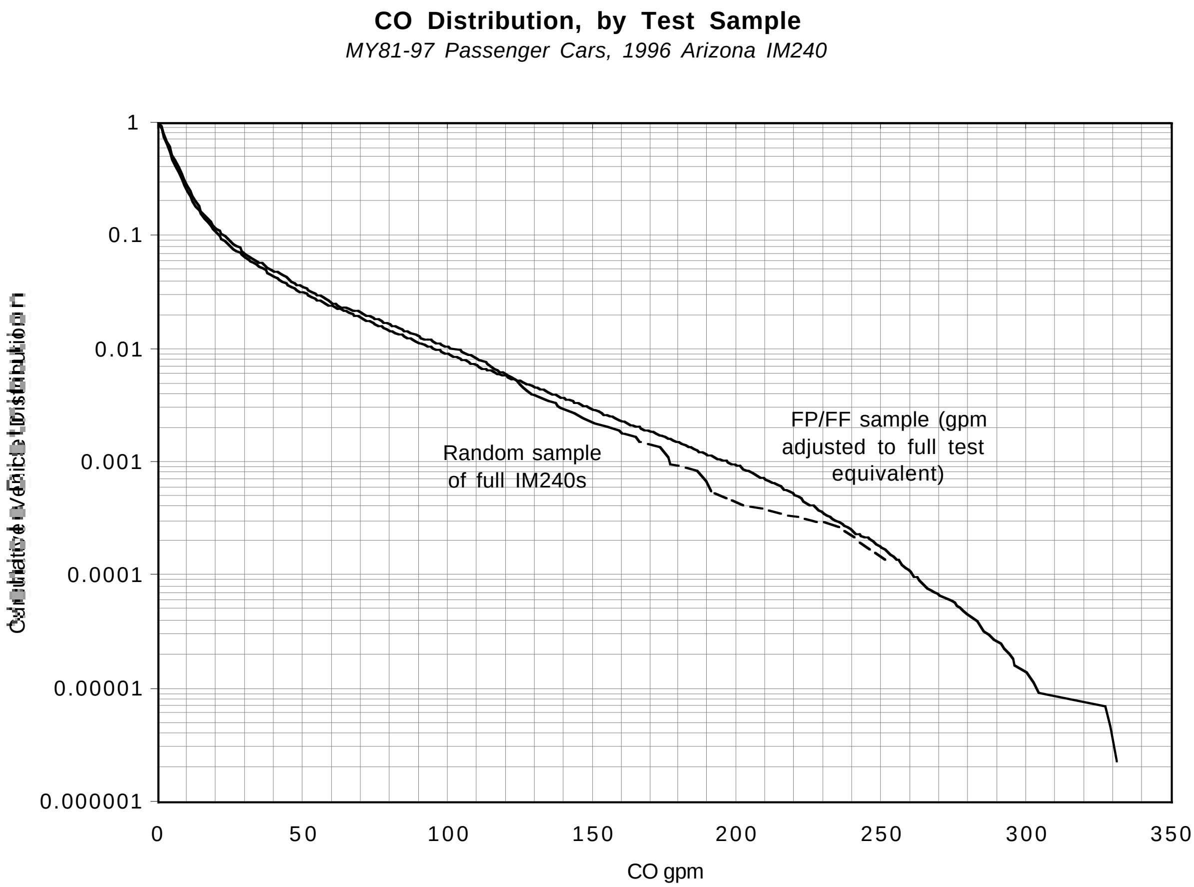
The next three figures show the emissions distributions of each pollutant by test sample. The figures indicate that the emissions distributions from both the random sample of full tests (dashed line) and the adjusted emissions from the FP/FF tests (solid line) are quite similar.

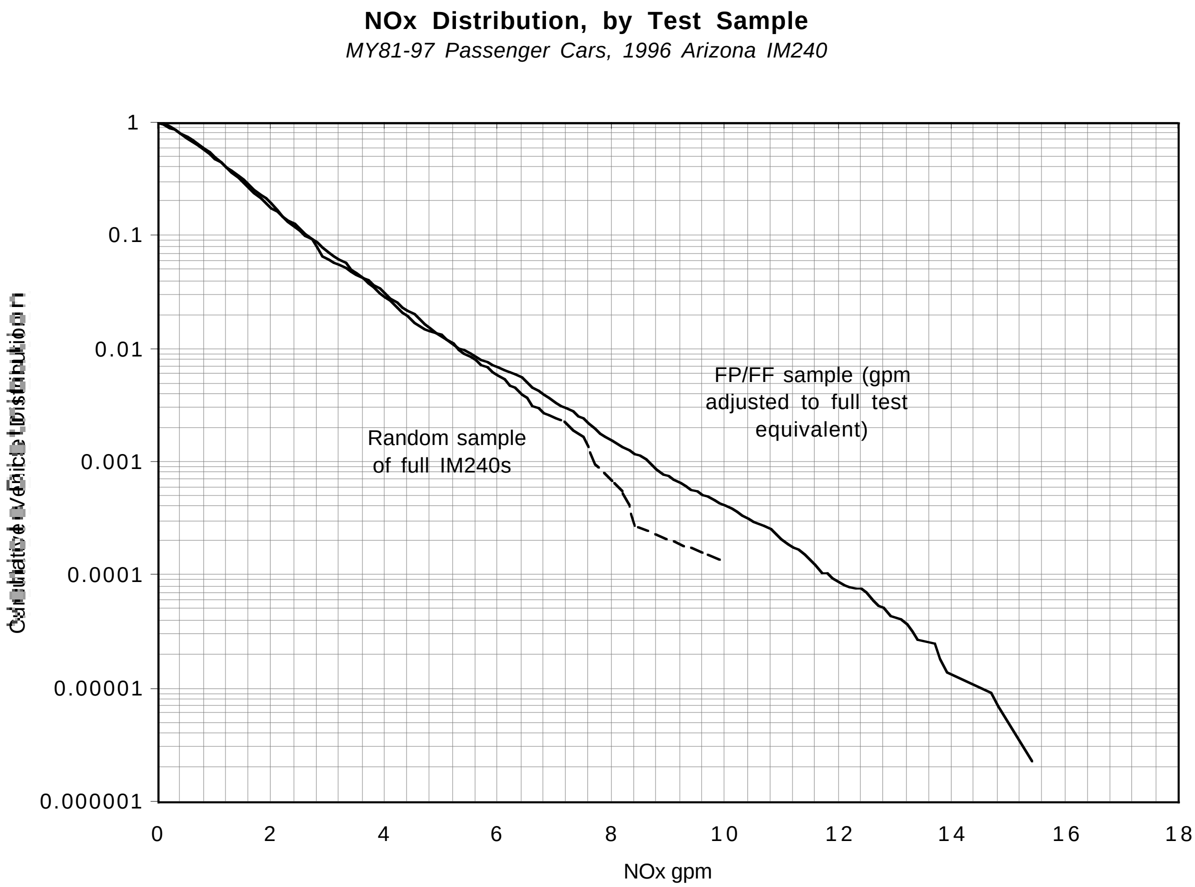
This similarity contradicts evidence presented earlier that the LBNL method underestimates the emissions of the majority of cars; that is, low emitting cars that pass after only 30 seconds of testing. We have not yet determined possible explanations for this discrepancy.

HC Distribution, by Test Sample

MY81-97 Passenger Cars, 1996 Arizona IM240




CO Distribution, by Test Sample
MY81-97 Passenger Cars, 1996 Arizona IM240
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0
50
100
150
200
250
300
350
CO gpm
Cumulative Distribution
Random sample of full IM240s
FP/FF sample (gpm adjusted to full test equivalent)



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